Blood Glucose Monitoring: At a glance

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This article will:

- Introduce Diabetes Mellitus Types 1 and 2
- Give rationale to the importance of blood glucose monitoring as a fundamental nursing skill especially for those nursing people with diabetes
- Support your understanding of how the human body regulates blood glucose
- Identify correct blood glucose ranges and those which may give cause for concern
- Recognise how to measure blood glucose accurately
- Provide a 'how to' guide on monitoring blood glucose using a glucometer
- Use contemporary evidence-based practice to underpin blood glucose monitoring practice

Diabetes Mellitus:

Diabetes Mellitus is a condition that results in elevated blood glucose levels (hyperglycaemia); continued elevation can contribute to progressive micro and macro vascular complications leading to renal, nerve and ocular damage, representing a significant contributor to morbidity and mortality (Bilous, Donnelly & Williams, 2010). Currently there are over 3 million people

(aged 18-99) diagnosed within the UK representing a population prevalence of 5.9%; 1 in 17 adults has diabetes Mellitus (IDF, 2017).

Type 1 Diabetes Mellitus (T1DM) represents approximately 10% of cases. The origin of the condition being autoimmune in nature, arising from the complete destruction of insulin secreting beta cells within the pancreas. Type 2 diabetes Mellitus (T2DM) accounts for the remaining 90% of cases and results from the reduced effective action of insulin. Eventually, leading to insufficient level of insulin production, to sustain appropriate blood glucose levels. T2DM is caused by a combination of genetic and ethnic predispositions, but predominantly lifestyle factors such as obesity and lack of physical exercise. Incidence is further correlated with increasing age (Holt, Kumar & Watkins, 2015).

Gestational diabetes mellitus (GDM) manifests with a degree of glucose intolerance with onset or first recognition in pregnancy. Individuals affected by GDM have an increased risk of developing diabetes after pregnancy (Buchanan *et al*, 2007).

There are several subtypes of diabetes outside T1DM, T2DM and GDM, including but not limited to genetic defects leading to diabetes, idiopathic diabetes (presenting with no underlying autoimmune cause), endocrinopathies, or drug and chemical induced diabetes. For these reasons, and the potentially mixed picture of diagnosis, it is less important to label the type of diabetes than it is to understand the mechanisms and importance of hyper and hypo glycaemia and treat accordingly (American Diabetes Association, 2013).

Rationale:

The measurement of blood glucose provides information on the effectiveness of blood glucose metabolism and guides interventions to achieve optimal glucose control within the body.

Glucose is a monosaccharide and is an essential fuel for the brain and other body cells formed as an end product of carbohydrate digestion (Maughan, 2008). Glucose is either metabolised

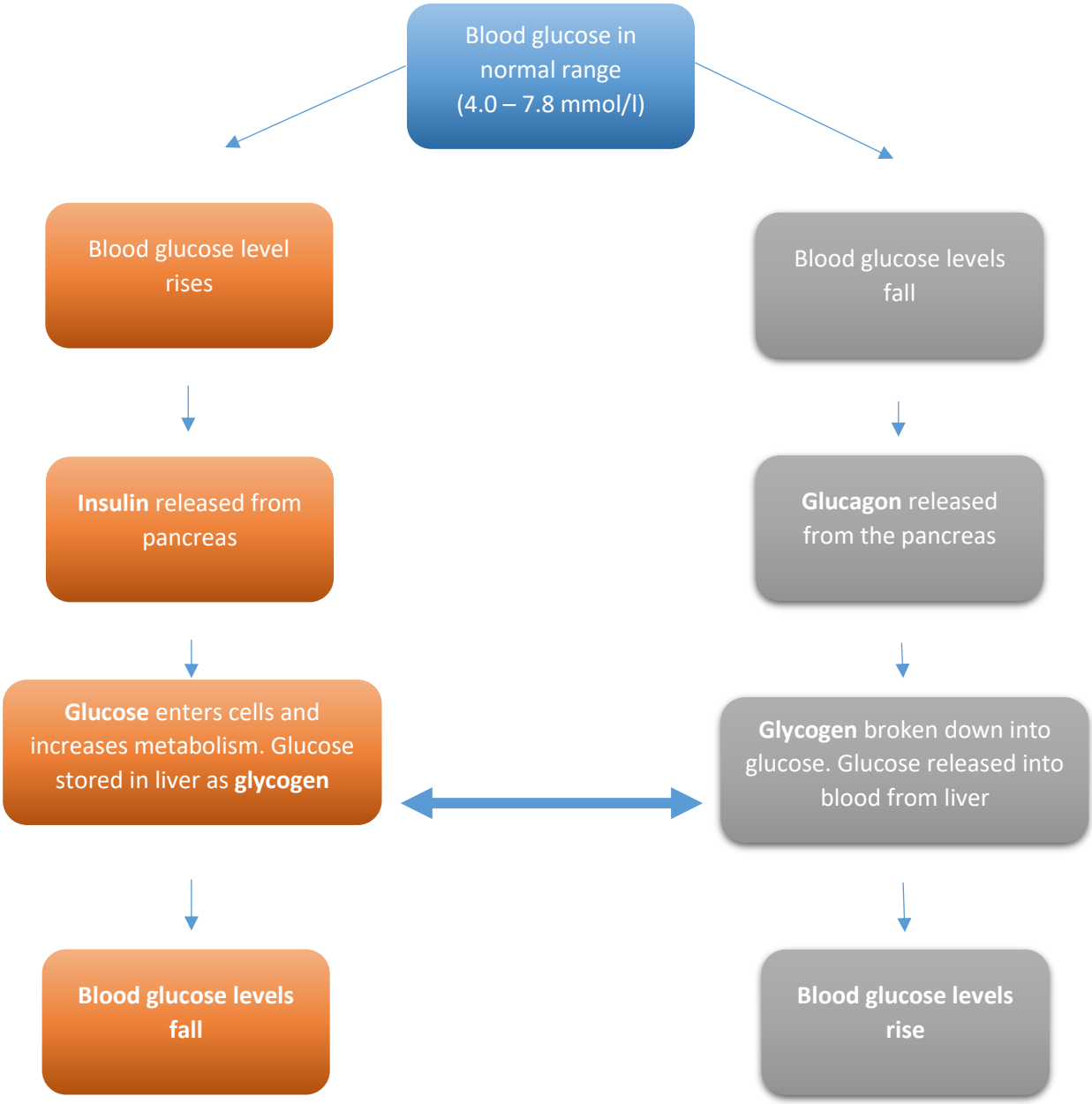
to produce energy or is stored in the muscles and liver as glycogen. Changes in glucose level after absorption of carbohydrate is termed the 'glycaemic response' (Sanders, 2016; Maughan, 2008). Regulation of normal glucose metabolism is shown in Figure 1.

The measurement of blood glucose is a key self-care activity for people with diabetes and has been shown to positively correlate with improved long –term glycaemic control (Shaji *et al* 2013; Shrivastava, Shrivastava and Ramasamy, 2013) and can function as a cue to action in diabetes self-management (Brackney, 2018).

The measurement of blood glucose is also a key nursing assessment for individuals:

- With T1DM and T2DM
- People with diabetes who have recently commenced or changed dosages of medication to increase insulin levels
- People with diabetes undergoing surgery
- People who are acutely sick
- In an emergency where consciousness level may be affected by low blood glucose (adapted from Delves-Yates, 2018a)

Figure 1: Regulation of normal glucose metabolism



Reference: Adapted from Boore *et al,* (2018)

Learning Point:

Type 1 diabetes results in an absolute absence of insulin therefore blood glucose levels continue to rise because glucose cannot enter cells to be metabolised and produce energy; excess glucose cannot be stored as glycogen. These individuals require insulin injections every day.

Type 2 diabetes causes cells to be less responsive to insulin and/or reduces insulin production by the pancreas; therefore, glucose entry into the cell is reduced resulting in increased blood glucose levels. Individuals may take medications to increase insulin production, to make cells more receptive to insulin or ultimately, may require injectable insulin

Point of care testing for blood glucose levels is managed with the use of bedside finger prick testing. Using this approach, capillary blood glucose monitoring provides immediate results of hypo and hyperglycaemia (Dougherty and Lister, 2015). In the past, urine test strips were utilised however, accurate measurements relied on stable renal function making the test potentially unreliable (Holt, 2014).

Target blood glucose ranges

Normal target ranges:

- Fasting plasma glucose level of 5-7 mmol/litre **and**
- Plasma glucose level of 4-7 mmol/litre before meals at other times of day

(NICE, 2015a)

Hyperglycaemia:

- Random plasma glucose of more than 11 mmol/litre (NICE, 2015b)

Hyperglycaemia describes any blood glucose concentration that is higher than recognised target ranges (Patton and Thibodeau, 2015). Prolonged hyperglycaemia can result in damage

to many organs of the body leading to renal failure, blindness or gangrene resulting in amputation (Boore, Cook and Shepherd, 2018).

Acute hyperglycaemia occurs when the body cannot utilise glucose due to insufficient or complete lack of insulin production. This causes the body to generate glucose via glycogenolysis (glycogen breakdown), lipolysis (fat breakdown) and gluconeogenesis (glucose derived from substrates such as lactate, glycerol and glucogenic amino acids). Blood glucose rises further, the person is effectively starving in a sea of plenty (Dean *et al*, 2004). Fatty acid metabolites know as ketone bodies, accumulate from this process, resulting in Ketoacidosis. Ketones are observed in the blood and urine (Marieb and Hoehn, 2015; Patton and Thibodeau 2015). Symptoms of hyperglycaemia are summarised in table 1.

Causes:

- Inadequate doses of insulin
- Infection
- Stress
- Surgery
- Medications (steroids, benzodiazepines)
- Various in nutritional intake
- Individuals receiving enteral / parenteral feeding
- Critical illness

(Marieb and Hoehn, 2015)

Table 1: Symptoms

Gastrointestinal	Nausea Vomiting

	Abdominal pain Hunger
Adrenergic	'Fight or flight response'
Respiratory	Tachypnoea
Renal	Glycosuria (excess glucose in urine) Polyuria (and dehydration) Polydipsia
Electrolyte imbalance	Excess ketones (from fat metabolism) Hypokalaemia Hyponatraemia
Liver and adipose tissue	Acetone breath
Cardiovascular	Cardiac irregularities
Central Nervous System	CNS depression – drowsiness Coma

(Adapted from Marieb and Kohen, 2015; Holt, Kumar and Watkins, 2015)

Learning Point: Diabetic Ketoacidosis (DKA)

- DKA results from severe hyperglycaemia and is a potentially life-threatening medical emergency
- DKA requires high intensity nursing within high dependency / critical care units
- In DKA urine will test positive for ketones and plasma ketones will be elevated
- DKA requires urgent hospital treatment with insulin, fluid and usually potassium replacement
- DKA leads to electrolyte imbalance due to excessive acidosis therefore close monitoring of electrolytes is required
- DKA may be the presenting feature of newly diagnosed T1DM

(Holt, Kumar and Watkins, 2015)

Learning Point: Hyperosmolar Hyperglycaemic Syndrome (HHS)

- HSS presents as extreme levels of hyperglycaemia without significant acidosis or ketones in people with T2DM (>40 mmol/l)
- Ketones may not be present as people with T2DM may still produce low levels of insulin
- May develop over weeks due to illness or dehydration
- Management is similar to that of DKA although less likely to require potassium replacement but may need sub cut heparin to prevent thrombotic complications
- Carries a higher mortality rate than DKA

Hypoglycaemia:

- Random plasma glucose of less than 4 mmol/litre

Hypoglycaemia occurs when blood glucose levels fall resulting in inadequate energy available to the brain leading to abnormal behaviour - sometimes mistaken for drunkenness (Patton and Thibodeau, 2015). If prolonged the individual may lose consciousness and if not treated may die (Boore, Cook and Shepherd, 2018)

The symptoms of hypoglycaemia are outlined in table 2.

Causes:

- Inadvertent insulin or sulphonylurea overdose (sulphonylureas work by increasing endogenous insulin production in the person with type 2 diabetes) or in response to a recent change in dose
- Missed or inadequate meal
- Unexpected exercise
- Error in timing of dosage

Table 2: Symptoms

Central nervous system	• Headache • Confusion • Concentration difficulties • Changes is personality
Cardiovascular	• Palpitations
Gastrointestinal	• Hunger • Nausea • Belching
Adrenergic	• Sweating • Anxiety

(Holt, Kumar & Watkins, 2015)

Hypoglycaemia treatment (NICE, 2018):

Mild – moderate hypoglycaemia:

- 10-20g glucose given by mouth either in liquid form (such as *GlucoGel*®) or as granulated sugar / sugar lumps / 4-5 Jelly Babies
- Repeat after 10-15 minutes
- After initial treatment a snack providing sustained carbohydrate release will minimise rebound hypoglycaemia
    - Alternatively:
        - 10g of glucose is obtained from 2 teaspoons of sugar / 3 sugar lumps and also from non-diet drinks i.e.: 100ml *Coca-Cola*®. Note that the carbohydrate content of some glucose drinks is currently subject to change – check the label

Severe hypoglycaemia (causing unconsciousness):

- Glucagon can be given by injection, which increases plasma glucose by mobilising glycogen stored in the liver.
- Give carbohydrate as soon as possible to restore liver glycogen stores
- Glucagon may be prescribed for use in an emergency.
- Alternatively, 20% glucose intravenous infusion can be given via a large gauge needle. 10% glucose may also be used. 50% glucose is not recommended due to potential extravasation injury.
- Blood glucose should be monitored closely, especially if there has been an overdose with long acting insulin or is due to an oral antidiabetic drug as hypoglycaemic effects may persist for many hours.

It is important to note that people with T1DM may become increasingly unaware that they are experiencing a hypoglycaemic episode as the number of episodes they experience increases. This is termed 'hypo unawareness'. People with T1DM should be assessed for their awareness of hypoglycaemia at each annual review with their doctor (NICE, 2015a).

Careful consideration must be given to the management of people with diabetes undergoing surgery as outlined in table 3.

Table 3: Management of people with diabetes mellitus undergoing surgery:

Target group	**Plan**
Well controlled T2DM	• Omit oral hypoglycaemic agent (if taken) on morning of planned surgery • Monitor plasma glucose • List first thing in the morning • Encourage eating and drinking within 1 hour
People on insulin / T1DM / Major elective surgery	• Blood glucose control should be optimised prior to surgery with referral to a specialist team if needed • Maintain blood glucose levels between 6-10mmol/l – regular monitoring of plasma glucose levels required • Intra-operative management achieved with intravenous insulin,

	glucose and potassium (variable rate intravenous insulin infusion VRIII) • Consider continuation of long acting insulin alongside VRIII in peri-operative period • Measure electrolytes once daily • Conversion to usual insulin regime once eating and drinking normally • Give first dose of subcutaneous insulin and a meal then discontinue VRIII • Person should be monitored carefully for hypo/hyperglycaemia

Reference: adapted from Holt, Kumar and Watkins, (2015)

Blood Glucose Measurement:

There are many devices available for 'point of care' (POC) testing. Several factors should be considered in the selection of meters, testing strips and lancets including:

- Assurance that the meter has been designed for use by non-laboratory staff
- Is the device suitable for the given setting (i.e.: critical care, in an ambulance, GP surgery)?
- Is the lancet / meter single or multiple use?

- Does the design of the equipment meet the needs of the user?
- Is the device CE marked?

Staff must be appropriately trained in the use of blood glucose meters, have an awareness of potential sources of error, be able to give advice and interpret results and have their competence recorded appropriately with access to regular updates. There must be a standard operating procedure / local policy in place to ensure testing is carried out in line with best available evidence and with access to the manufacturer's guidance on the use of all blood glucose monitoring equipment (MHRA, 2013)

Equipment:

- Personal protective equipment (non-sterile gloves, apron)
- Blood glucose meter
- Single use lancet
- Test strips
- Cotton wool / low linting gauze
- Sharps box
- Control solution

(Delves-Yates 2018b)

Table 4 outlines the correct procedure to perform blood glucose monitoring.

Table 4: 'How to' perform blood glucose monitoring

Step	Procedure	Rationale
1	Turn on the machine and ensure correct date and time are displayed and that there is adequate	• To ensure safety • To ensure accuracy of result recorded

	battery. Scan operator ID if required as per local policy	
2	Ensure the unit of measurement is mmol/L	• To ensure accurate measurement
3	Ensure equipment set up, this may vary according to the device or if automated systems are used. Always follow manufacturer guidelines and local policy. Checks may include: • Test strips are in date and have not been left exposed to air • The monitor and strips are calibrated together • Quality control testing is checked and carried out if required as per local policy and documented • Meter was decontaminated after previous use • The screen and display are intact	• To minimise failure of device / equipment
4	Identify the individual verbally and check against the wrist band	• To ensure correct person is tested • To gain consent for the procedure
5	Select an appropriate site, consider: • Skin condition – site should be well perfused and free of callouses	• Rotating sites and avoiding previous puncture areas reduces

	• Avoid burns, cuts, scars, bruises, rashes • Avoid areas that have been subject to continual testing • Usual sites include the distal segment of the 3rd or 4th finger	soreness and callous formation • Tips, pads of fingers and the index finger should be avoided as they have a dense supply of nerve endings and testing may be more painful
6	Ask person to sit / lie down	• Ensures safety by minimising risk of fainting
7	Ask the person to wash hands with soap and water and dry with low-linting gauze	• Removes any contaminant which may give misleading readings
8	Practitioner to wash hands and don gloves and observe universal precautions as per local policy	• To ensure safety by minimising cross infection
9	Take a single use lancet and ensure correct setting is used if depth setting can be adjusted	• Single use lancets minimise cross contamination and limit needle stick injury • Adjusting the depth setting ensures minimal discomfort

10	Remove the device cap if present; activate the lancet as per manufacturer's guidance at the selected site. Utilise the side of the finger. Rotate sites Single use devices should be used in the in-patient setting to avoid cross contamination. In the persons own environment a reusable device may be used If there is difficulty obtaining the blood sample, 'milking' from the palm of the hand will increase droplet size, do not milk the finger alone	• The side of the finger is less sensitive and is easier to obtain blood from • Sites are rotated to avoid infection, callous formation and to minimise pain • Milking the finger alone can cause contamination of the sample by interstitial fluid leading to a low reading
11	Dispose of the lancet as per local policy	• To minimise cross contamination • To minimise risk of sharp injury
12	Insert the test strip into the blood glucose meter. Ensure meter is ready for droplet. Apply the first drop of blood and ensure the window is entirely covered with blood	• Inadequately filled strips leads to inaccurate results or error reports
13	Apply gauze and pressure to puncture site, monitor for excessive bleeding	• To ensure safety • To minimise bleeding
14	Remove gloves and apron, dispose of as per local policy, carry out hand hygiene as per local policy	• To prevent infection

15	Document result and sign as per local policy	• To ensure accurate record keeping
16	Dock the machine / return the machine to its usual location	• To log centralised records • To charge battery • To ensure machine is located in a predesignated area for further use
17	Report any results outside of normal ranges	• To ensure changes in blood glucose are treated appropriately to maximise glycaemic control
18	Ensure the person is comfortable and receiving appropriate care	• To ensure safety • To maximise satisfaction

Reference: Adapted from Dougherty and Lister (2015)

Errors in results:

Potential sources of error include:

- Incorrect meter calibration
- Poor meter maintenance
- Incorrect operator technique
- Inadequate quantity of blood on test strip (gives false low readings)

- Out of date / improperly stored test strips (give false low readings)
- Potential for error in low blood glucose range
- Contamination of the sample may arise from substances present on the test-finger:
    - Alcohol gel or wipes used to clean the finger
    - Newspaper print, perfumes, hand creams, hairspray, hair gel
    - Residues of food and drink

(Dougherty and Lister, 2015; Hortensius *et al* 2011; Trend UK, 2017)

Interferences and contraindications to POC testing are detailed in table 5.

Table 5: Contraindications / interferences in POC testing:

Contra-indication	**Example**
Dialysis treatment	Some fluids may contain Maltose which can interfere with test strip methodology
Peripheral circulatory failure	Severe dehydration, DKA, hypotension, shock, peripheral vascular disease
Severe dehydration	Vomiting or diarrhoea, diuretics, uncontrolled diabetes
Variations in blood oxygen tension	People receiving intensive oxygen therapy
High concentrations of non-glucose reducing substances in the blood	Intravenous infusion of ascorbic acid
High bilirubin values	Jaundice
Extremes of haematocrit	Neonatal blood samples, pregnancy
Hyperlipdaemia	Total parenteral nutrition, hyperlipidaemia

Reference: MHRA (2013)

Monitoring and reporting

Accurate records of blood glucose monitoring are essential to ensure safety. Records should include results, test strip lot number, meter maintenance records, calibration and quality control testing, patient and operator identity and battery change (MHRA, 2013). Technology is now available to utilise wireless devices for POC testing which allow electronic data capture and documentation of results, device testing and operator identification, directly linked to the medical records (Cobas, 2018).

Self-monitoring

Within the community setting routine self-monitoring of blood glucose levels is advised for all people with T1DM, ideally at least 4 times per day; before each meal and before bed (NICE, 2015a). People with T2DM can also self-monitor blood glucose if they require insulin, have evidence of hypoglycaemia, or if pregnant or planning pregnancy (NICE, 2015c).

Technologies are available which now enable people with diabetes to continuously monitor and manage their blood glucose and review results via mobile devices. In November 2017, the Abbott Freestyle Libre continuous glucose monitor device was made available through the NHS formulary for people with T1DM who meet specific criteria. The device continuously measures glucose levels within interstitial fluid, utilising a sensor applied to the skin (NICE, (2017). These devices will become increasingly prevalent in coming years.

Consideration should be given when people who routinely monitor their own blood glucose are admitted to hospital. There is conflicting evidence as to the continuation of self-monitoring in the in-patient setting. Whilst some authors highlight the complexity of hospital treatment and its effect on normal glucose control as a factor which makes self-monitoring beyond the ability of the individual to manage their own blood glucose (Shah and Rushakoff, 2015); others

counter this argument highlighting that removing self-monitoring may place the person at increased risk of hypo or hyperglycaemia (Mabrey and Setji, 2015).

However, there is consensus that cooperative management and partnership with people with diabetes should be encouraged to maximise satisfaction and clinical outcome.

Recommendations and developments:

Timely internal quality control including unit calibration must be carried out as per local policy and manufacturer's guidance to ensure the device is working correctly and results are reliable. External quality assessment (EQA) should also be implemented using the analysis of standardised test samples with an undisclosed value from an external source. Participation in an EQA scheme allows comparability across sites and can often be coordinated through laboratory departments (MHRA, 2013). Holt, Kumar and Watkins (2013) suggest the use of technologies that utilise existing wireless POC testing to integrate with a diabetes data management system to proactively institute timely changes in diabetic management. Electronic prescribing further enhances this safety focus.

Conclusion:

All nurses should be familiar with the importance of blood glucose monitoring and the procedure to carry out testing safely and effectively. Appropriate and timely monitoring of blood glucose will allow for the appropriate management of blood glucose, which falls out of target ranges. This will ensure ongoing safety during episodes of acute illness or effective management of diabetes mellitus in the longer term, minimising future diabetic related health complications.

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